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METHOD AND APPARATUS FOR HEATING DIELECTRIC MATERIALS

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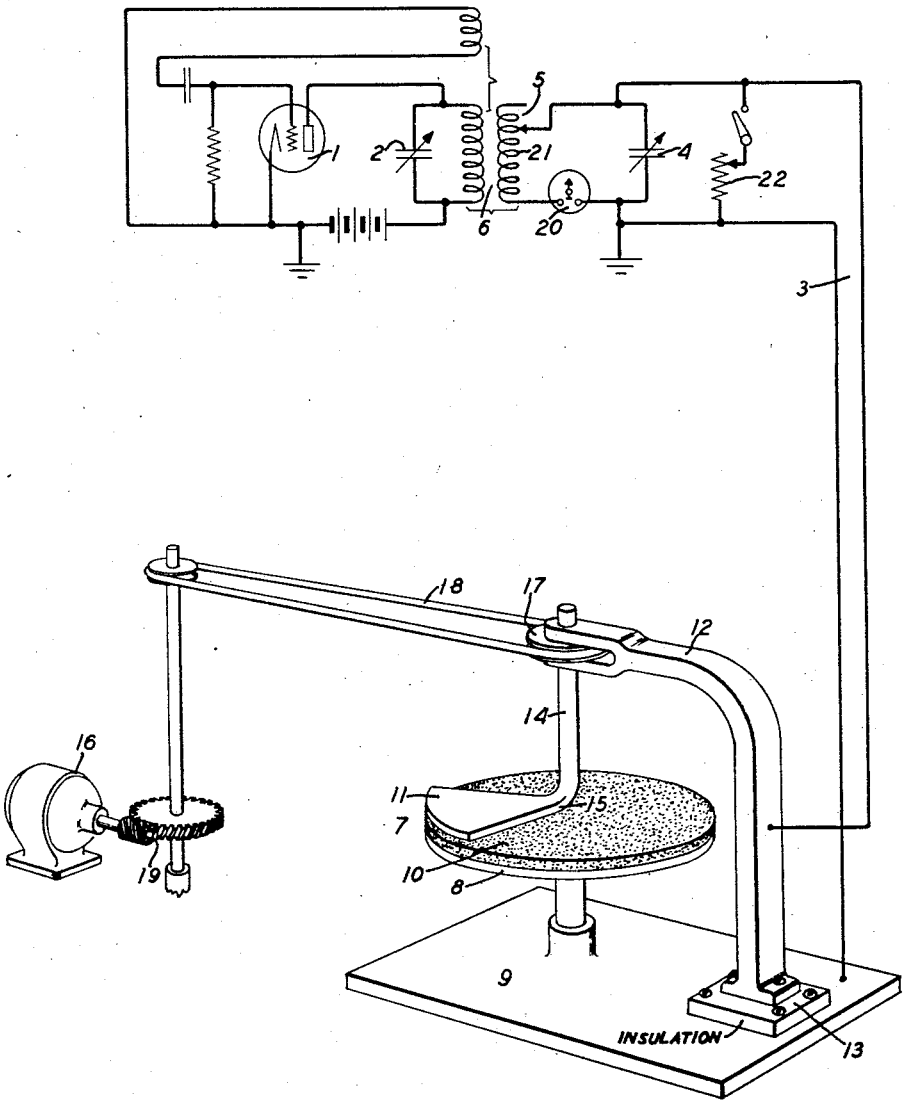

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METHOD AND APPARATUS FOR HEATING DIELECTRIC MATERIALS

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6 Claims. (Cl. 219—47)

This invention relates to heating systems for dielectric materials and the object of the invention is to heat such materials uniformly and substantially simultaneously throughout their mass.

Due to their low heat conductivity, it is difficult to heat such materials quickly and uniformly by the external application of heat without subjecting the outer layers of the material to such high temperatures as to impair their physical properties.

It has been proposed heretofore to heat such materials simultaneously throughout their mass by means of the dielectric loss produced in them when they are subjected to a high voltage, high frequency field. While this method has proved very effective in reducing the time required to heat such materials, considerable difficulty has been encountered as a result of the tendency of the materials to heat more rapidly in one or more spots than in others.

According to this invention, more uniform heating is obtained by subjecting only a portion of the material at a time to the action of the field and continuously varying the area of the material in which the loss is produced. This may be accomplished in various ways, such for example, as by using two electrodes, one of which is smaller than the other, and moving the smaller electrode successively into opposed relationship to the several portions of the other electrode. In the preferred embodiment one electrode supporting the material is circular and the other or upper electrode is a sector of a circle and is mounted on a vertical shaft for rotation with a small air-gap between it and the material. With this type of moving electrode a small central area under the shaft is continuously subjected to the field and to avoid excessive heating at this point the shaft and the adjacent portion of the electrode are preferably cut away sufficiently to produce the necessary reduction in heating effect.

These and other features of the invention will be more clearly understood from the following detailed description and the drawing which shows a suitable power supply circuit and one form of moving electrode and its driving mechanism.

The vacuum tube oscillator 1 which should be capable of delivering power of the order of 1 kilowatt is tuned to a high frequency such as 10 to 20 megacycles by a condenser 2. Inductively coupled to the plate coil of the oscillator is a load circuit consisting of the coil 21 of the transformer 6 tuned by the combined capacity of the variable condenser 4 and of the heating unit 7 which are connected in parallel by the lead 3. An ammeter 20 measures the high frequency current flowing in the load circuit and provides a convenient means for indicating the degree of coupling between the load circuit and the oscillator as determined by the position of the movable coil 21.

The heating unit 7 comprises a lower stationary electrode 8 mounted on the base plate 9 and supporting the material 10 to be heated, and an upper electrode 11 supported for rotation by the arm 12 which is insulated from the base plate by a suitable insulator 13. The electrode 11 is a sector of a circle of perhaps 60 degrees, but the choice of its size will be dictated by various factors such as the nature of the material to be heated and the frequency of the oscillator. The axis of the shaft 14 is concentric with the lower electrode 8 and the lower end 15 of the shaft and the adjacent portion of the sector are preferably cut away as shown, to prevent excessive heating at the center of the material.

During the heating operation the electrode 11 is slowly rotated by any suitable means such as a motor 16 connected to the pulley 17 by a belt 18 and worm gearing 19. In operating the system the load circuit is tuned by the condenser 4 and contact 5 until the current is a maximum as indicated by the radio frequency meter 20. Then the coupling between the coil and the oscillator is adjusted for optimum transfer of energy to the heating circuit. These adjustments and the alternative adjustments described below are preferably made with the electrode 11 rotating, or at reduced oscillator power to avoid excessive heating of the material.

As the material heats due to the dielectric loss produced in it by the field set up between the electrodes, two effects will be observed. With most materials both the dielectric constant and the power factor will become larger. Any change in the dielectric constant will produce a detuning effect in the heating circuit thereby reducing the energy delivered and retarding the heating rate. An increase in the power factor increases the equivalent series resistance of the secondary tuned circuit, the current in the circuit 3 decreases and the heating action is correspondingly decreased.

When the rotating electrode of applicant's system moves over a portion of the material in which an excessive temperature is developing, the current is automatically reduced due to both of these effects and relatively less heat is generated

in this portion of the material than in those portions of lower temperature. In this way any tendency toward localized overheating is checked and the temperature is raised substantially uniformly throughout the whole mass of the material.

If the dielectric constant and power factor of the material to be heated increase rapidly with temperature, the resulting reduction in the load circuit current may unduly prolong the heating process or even prevent the material from reaching the desired final temperature. To offset the effect of excessive change in the dielectric constant, the load circuit may be initially detuned with respect to the oscillator frequency so that the change in the dielectric constant, as the temperature of the material rises, brings the load circuit into resonance. A further rise in temperature carries the tuning beyond resonance and automatically retards further heating.

If the material is of such nature that its power factor does not change appreciably with temperature and the coupling between the winding 21 and the primary of the transformer 6 is adjusted to its optimum value with the material at ambient temperature, the power transmitted to the load circuit will be substantially a maximum at all temperatures. The power factor of most materials, however, will vary considerably with temperature and hence a load circuit containing such a material, which is initially suitably coupled to the oscillator, will depart from this condition as the heating progresses, and the heating is correspondingly retarded.

To offset this effect of a large variation in power factor, the initial coupling should therefore be somewhat greater or less than the optimum value depending on whether for the particular material to be heated, the power factor increases or decreases. Then, as the heating progresses, an impedance match occurs at some intermediate temperature the choice of which will depend on such factors as the rapidity of heating and the degree of automatic regulation desired.

If, as in the case of many materials, both the dielectric constant and the power factor increase considerably with temperature, the load circuit initially should be tuned to a frequency somewhat higher than that of the oscillator and the coupling should be somewhat greater than the optimum value. When these adjustments have been properly made the heating will then be accelerated during initial increases in the constants of the material, but excessive heating in any region will bring about sufficient modification of the load circuit constants to retard further heating.

It will be understood, however, that the exact procedure in adjusting the system to produce the compensating effects desired in a particular case will depend on the nature of the material to be heated, the rapidity of heating and the final temperature required and other factors such as the relative capacities of the condenser 4 and heating unit 7.

If the system is found to be unstable when operating with maximum transfer of power to the heating circuit a buffer stage of amplification may be used between the oscillator and the load circuit or the coupling adjustment may be made less critical by the use of a shunt resistor 22. Such a resistor also has the advantage of reducing the effects of a large variation with the temperature in the power factor of the material being heated.

What is claimed is:

1. In a heating system for dielectric materials, a source of high frequency potential, electrodes connected to the source and producing an electric field in a portion of the material to be heated, and means for moving one of the electrodes to subject all portions of the material to the action of the field in cyclic sequence.

2. In a heating system for dielectric materials, a source of high frequency potential, electrodes of different sizes connected to the source and producing an electric field between them, and means for producing relative motion between the material to be heated and one of the electrodes whereby all portions of the material are subjected to the action of the field in cyclic sequence.

3. In a heating system for dielectric materials, a source of high frequency potential, electrodes connected to the source and disposed on opposite sides of the material to be heated, one of the electrodes being substantially smaller than the other, and means for moving the smaller electrode into opposed relationship to the several portions of the other electrode in cyclic sequence.

4. In a heating system for dielectric materials, a relatively large stationary electrode supporting the material to be heated and a relatively small electrode in the form of a sector disposed above said material, a source of high frequency potential connected to the electrodes and producing an electric field between them, and means for slowly rotating the small electrode to subject the several portions of the material in cyclic sequence to the action of the field.

5. In a heating system for dielectric materials, a large circular stationary electrode supporting the material to be heated, a small electrode in the form of a sector, means for mounting the small electrode above said material comprising a vertical shaft concentrically mounted with respect to the circular electrode, means for rotating the shaft, and a source of high frequency potential connected to the electrodes, the small electrode being contoured adjacent the shaft to prevent excessive heating in the central portion of the material.

6. The method of regulating the heating of dielectric materials under the action of a high frequency electric field which comprises initially adjusting the coupling between the heating circuit and the source of high frequency oscillations to a value other than the optimum value such that the variations with temperature in the power factor of the material bring the coupling to its optimum value at a temperature within the desired heating range.

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